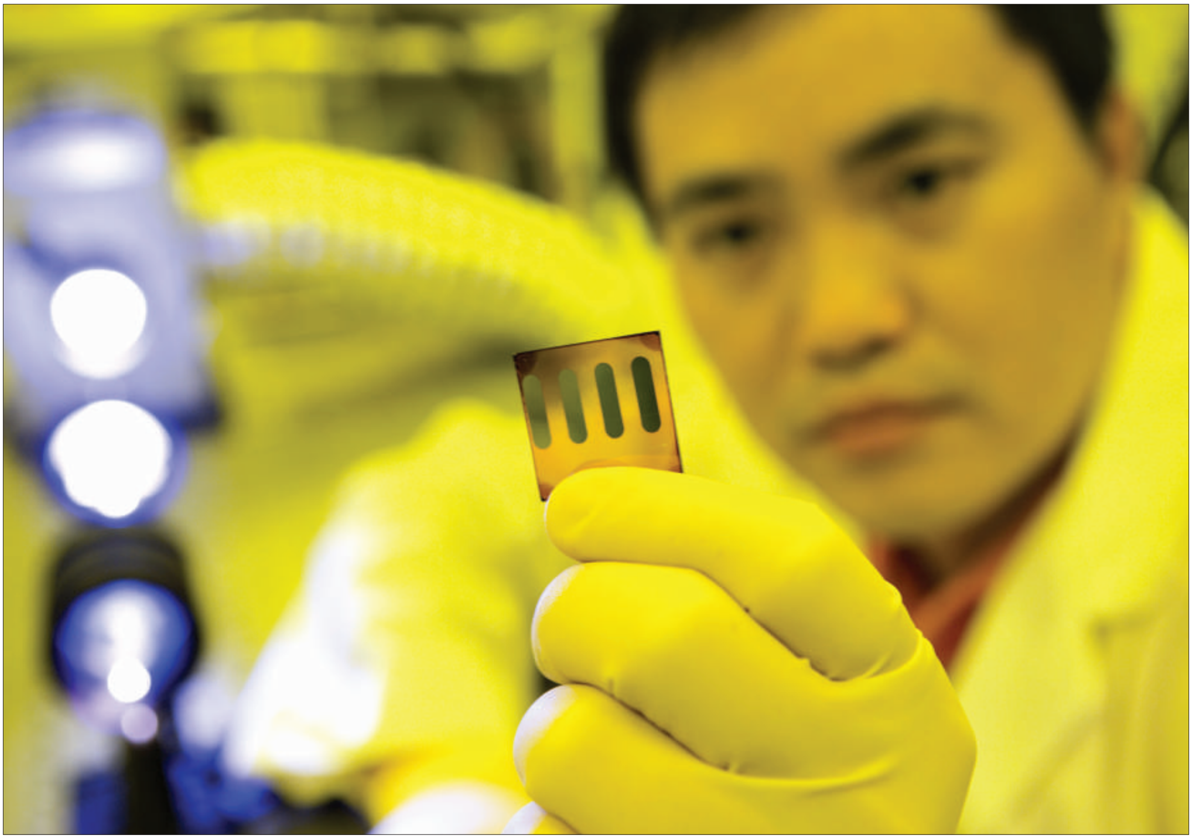

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Research Article
Index Models Assessment of Heavy Metal Pollution in Soils within Selected Abattoirs in Port Harcourt, Rivers State, Nigeria

Edori Onisogen Simeon and Kpee Friday

Department of Chemistry, Ignatius Ajuru University of Education, PMB 5047 Rumuolumeni, Port Harcourt, Nigeria

Abstract

Background and Objective: Soil pollution is a worldwide phenomenon which results from both natural and anthropogenic activities. This has resulted in several health and physiological problems in both plants and animals. This study investigated the effect of abattoir on heavy metals content of the soils within the immediate vicinity. **Methodology:** Soils from three abattoirs (Agip, Iwofe and Mile III) in Port Harcourt were analyzed for heavy metals using atomic absorption spectrophotometer. The data obtained were further subjected to index models (contamination factor, pollution index, geo-accumulation and enrichment factor) analysis. **Results:** The data obtained showed iron (Fe) to be most concentrated in the soils and ranged from 59.36$\pm$5.21 to 81.70$\pm$7.10 mg kg^{-1}, this was followed by the value recorded for zinc (Zn) which was between 8.17$\pm$1.96 to 14.33$\pm$2.43 mg kg^{-1} and was followed by the value observed for copper (Cu) being in the range of 4.70$\pm$1.27 to 9.57$\pm$2.86 mg kg^{-1}. The least observed metal in all the sample stations was cadmium (Cd) which ranged from 0.0011$\pm$0.00 to 0.0067$\pm$0.00 mg kg^{-1}. When the concentration of the heavy metals were subjected to different index models, contamination factor (C_f) revealed slight contamination of the different soils from different stations by Cu. There was also slight contamination of the soil by Zn and nickel (Ni) at the Mile III sample station. At the Mile III station, the soil was slightly polluted with arsenic (As). **Conclusion:** However, the general view of Pollution Index (PI) showed that the soils are uncontaminated with the heavy metals. Geo-accumulation index and enrichment factor showed that the soils were free form pollution. The observed concentrations of the heavy metals showed that the soils are not polluted by heavy metals. Also, the model indices showed that the sources of the heavy metals were from anthropogenic sources and are slightly different from the background values.

Key words: Soil, contamination factor, pollution index, geo-accumulation index, enrichment factor

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Corresponding Author: Edori Onisogen Simeon, Department of Chemistry, Ignatius Ajuru University of Education, PMB 5047 Rumuolumeni, Port Harcourt, Nigeria

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The advent of industrial revolution has led to widespread environmental pollution and contamination. Different pollutants are discharged into the environment through anthropogenic (agricultural and industrial) activities[1,2] and natural sources. Pollutants discharged into the environment often come in the form of wastes from the relevant pollution sources[3]. Heavy metals which are part of these pollutants, often in most cases are present in trace concentrations. Most of these metals even though may be present in very low concentrations are toxic to the environment and often results in bioaccumulation or bioconcentration in animal and plant tissues[4,5]. The increased content of heavy metals in an environment can contribute to negative health effects of that environment[6]. The quantity of heavy metals introduced into the soil will increase the heavy metal build-up of the soil and thus increase the concentration of both essential and non-essential metals in the soil[7] and also, affect the physical and chemical properties of the soil.

Metals are natural components earth's crust and are contributors to the natural balance of the planet. Human activities help in the distribution, concentration and chemical modification or changes of these metals in forming complexes which finally culminates in the toxicity of these metals[8]. The presence of heavy metals and organic compounds in the soil alters the quality of the soil and ground water[9,10]. The soil is a natural sink and therefore receives as much quantity of pollutants and contaminants as possible. The deposition of metallic ions in the soil is known to influence the physicochemical properties, mobilization, release, sorption and adsorption characteristics of the soil[2].

Adesemoye *et al.*[11] reported that in many parts of the world, human activities which includes rearing of animals and processing of meat has negative consequences on the soil and the composition of water. An abattoir is a specialized environment where animals are slaughtered and processed for their meat. These premises are duly approved and registered by government regulatory agencies so that the slaughtering of animals can be done with utmost hygiene and also proper inspection could be carried out during the processing, preservation and storage of the meat for human consumption[12]. However, the disposal of the waste generated from slaughter houses are done without consideration to legislative conditions or principles[13]. Therefore, the possibility of environmental contamination and pollution from abattoir cannot be over ruled.

This study was undertaken to examine the concentration of heavy metals in soils from selected abattoir (slaughter house) in Port Harcourt metropolis.

MATERIALS AND METHODS

Sample location and collection: Three sample stations (abattoirs) namely Mile III, Mgbuosimini (Agip or Ayagologo) and Rumuolumeni (Iwofe) as shown in Fig. 1 were selected. Soil samples from these abattoirs were collected from a depth of 10 cm with soil auger. A composite sample was formed from five collections within an abattoir. Three composite samples were collected from a sample station. The soil samples were put into polythene bags and then transported to the Chemistry Department, Laboratory of the Ignatius, Ajuru University of Education for further treatment.

Sample preparation and digestion: The samples were air dried to constant weight and then oven dried at a temperature of 105°C. The soil samples were then ground to powder in a porcelain mortar. Stones were removed without crushing them. The ground soil was sieved with 2 mm mesh to obtain a fine powder. The powdered soil was then digested according to the method described by Edori and Edori[14]. The digest were examined for the heavy metals using Atomic Absorption Spectrophotometer (A.A.S.), solaar thermo elemental flame atomic absorption spectrometer, model SE-71096 made in Germany, with a detection limit of 0.001 mg kg^{-1} at the Jaros inspection services limited along rumuolumeni road. The data is presented as triplicate determination of each metal and expressed as Mean±SD.

Pollution index models

Contamination factor (C_f): The standard employed for the interpretation of the contamination factor values was adopted from Lacatusu[15]. The contamination factor was used to ascertain the levels of soil contamination by heavy metals. Contamination factor is the ratio of the concentration of the heavy metal to the background value. They are classified on a value range of 1-6. Contamination factor is given in Eq. 1:

$$\text{Contamination factor } (C_f) = \frac{Cm}{C_b} \quad (1)$$

where, Cm is the concentration of the metal, C_b is the background value. The DPR[16] target value for heavy metals (Table 1) was taken as the background value. The range for the significance of intervals of contamination is given in Table 2.

Pollution Index (PI): Pollution index is a measure of the degree of overall contamination in a sample station. The procedure of Tomlinson *et al.*[17] was used to calculate the Pollution Index (PI) for each site give in Eq. 2:

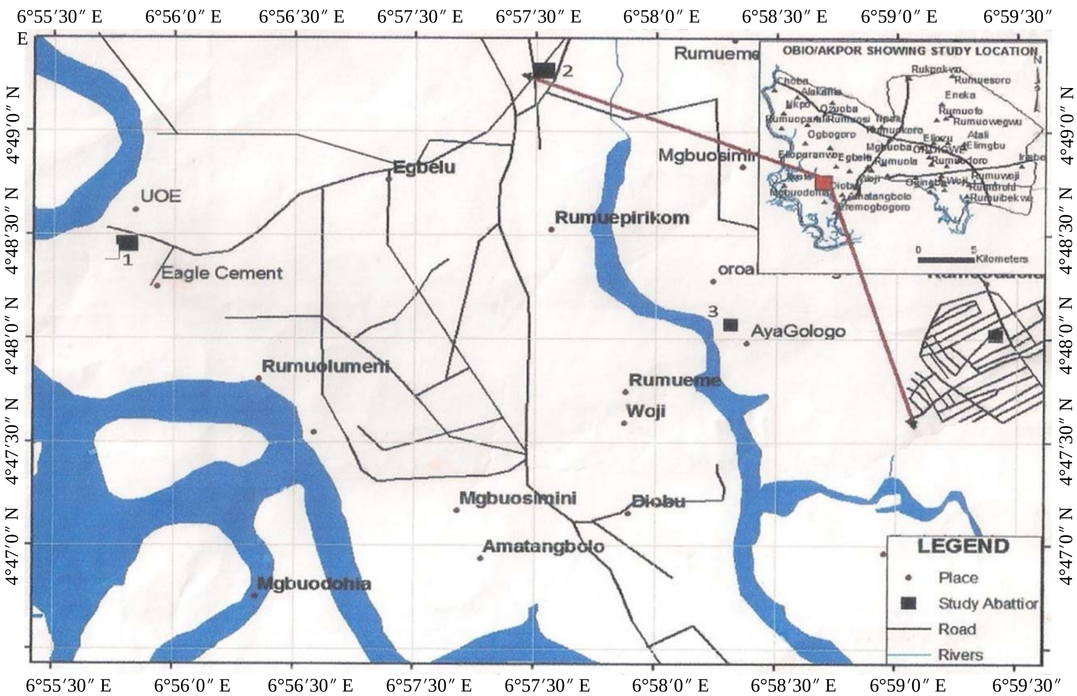

Fig. 1: Map of the study area

Source: Digitized from google image

Table 1: Target values for heavy metals (mg kg^{-1})

Metals	Target values (mg kg^{-1})	Intervention values (mg kg^{-1})
Iron (Fe)	38000	-
Zinc (Zn)	140	720
Lead (Pb)	85	530
Cobalt (Co)	20	240
Copper (Cu)	36	190
Chromium (Cr)	100	380
Nickel (Ni)	35	210
Manganese (Mn)	850	-
Arsenic (As)	1.0	10
Cadmium (Cd)	0.8	17

Source: DPR[16]

$$PI = (C_f1 \times C_f2 \times C_f3 \times ....C_fn)^{1/n} \quad (2)$$

where, n is the No. of metals and C_f is the contamination factor. The C_f is the metal concentration in soil/background values of the metals. The PI is a potent tool used in heavy metal pollution assessment. Pollution range and their significance is shown in Table 2.

Geo-accumulation index (Igeo): The formula proposed by Muller[18] was used to calculate the geo-accumulation index (Igeo) values for the various metals is given in Eq. 3:

Table 2: Significance of intervals of contamination factor/pollution index (C_f/PI)

C_f/PI	Significance
<0.1	Very slight contamination
0.10-0.25	Slight contamination
0.26-0.5	Moderate contamination
0.51-0.75	Severe contamination
0.76-1.00	Very severe contamination
1.1-2.0	Slight pollution
2.1-4.0	Moderate pollution
4.1-8.0	Severe pollution
8.1-16.0	Very severe pollution
>16.0	Excessive pollution

Source: Lacatusu[15]

$$Igeo = \log2 (Cn/1.5Bn) \quad (3)$$

where, Cn is the concentration of the element in the soil, Bn is a geochemical background for the element or world average of the element in shale. Seven classes (ranging from 0-6) of the geo-accumulation index was proposed by Muller[18] to classify the level of contamination of the soil or sediment by the metals. These are:

Class 0 = $Igeo \leq 0$ (practically uncontaminated)

Class 1 = $0 < Igeo < 1$ (uncontaminated to moderately contaminated

Class 2 = $1 < Igeo < 2$ (moderately contaminated)

Class 3 = 2<Igeo<3 (moderately to heavily contaminated)
Class 4 = 3<Igeo<4 (heavily contaminated)
Class 5 = 4<Igeo<5 (heavily to extremely contaminated)
Class 6 = 5<Igeo>6 (extremely contaminated)

Any value that falls from 6 and above is classified in the open class. In class the value of the element can be as many folds greater than the background value of the metal or element[18].

The background value taken is considered from world average value in shale (mg kg^{-1}) of the metals determined in the study. The values are Fe = 47200, Zn = 95, Pb = 20, Co = 19, Cu = 45, Cr = 90, Ni = 68, Mn = 850, As = 13 and Cd = 0.3.

Ecological risk factor: Ecological risk factor (Er) which was suggested by Hakanson[19] is the quantitative expression of potential ecological risk of a given contaminant and is defined as the ratio of the toxic response factor to the contamination factor for a given contaminant or pollutant is given in Eq. 4:

$$Er = Tr \times C_f \quad (4)$$

where, Tr is the toxic-response factor for a given contaminant and C_f is the contamination factor.

The terminologies used to describe the ecological risk factor are divided into five categories:

- Er<40 (low potential ecological risk)
- 40≤Er<80 (moderate potential ecological risk)
- 80≤Er<160 (considerable potential ecological risk)
- 160≤Er<320 (high potential ecological risk)
- Er≥320 (very high ecological risk)

The aim of the risk factor was originally a diagnostic tool for water pollution control, but has presently been used for assessing sediments and soils quality of an environment contaminated by heavy metals.

RESULTS AND DISCUSSION

Heavy metals: The concentration of the heavy metals in the soils within the various abattoirs is shown in Table 3, while the Spearman's correlation coefficient between metal concentrations is shown in Table 4.

The most abundant metal recorded in the different abattoir was iron (Fe) which was followed by zinc (Zn). The lowest metal content in the soil within the vicinity of abattoir was cadmium (Cd). The concentrations of the heavy metals in the soil were all below the acceptable limit in soil as recommended by DPR[16] and the values of those observed by Nasiru *et al.*[20] and Chukwu and Anuchi[21] in Gombe abattoir, Gombe state and abattoir in Port Harcourt, Rivers State in Nigeria . This is an indication that the soil is not polluted by heavy metals through the activities practiced within the abattoir.

Despite the usefulness of some of these heavy metals to humans in some ways, for example in alloys, on the other hand, they pose negative consequences on humans in particular and the environment at large at high concentrations. The concentration of heavy metals in soil within an abattoir can be influenced by secondary wastes

Table 3: Heavy metal content in soils from selected abattoirs in Port Harcourt

Metals (mg kg^{-1})	Stations		
	Agip	Iwofe	Mile III
Iron (Fe)	72.84±6.22	59.36±5.21	81.70±7.10
Zinc (Zn)	8.170±1.96	11.72±3.45	14.33±2.43
Lead (Pb)	0.970±0.00	1.930±0.00	2.120±0.04
Cobalt (Co)	0.024±0.00	0.017±0.00	0.370±0.01
Copper (Cu)	4.700±1.27	6.120±2.13	9.570±2.86
Chromium (Cr)	0.940±0.03	1.900±0.00	2.970±0.29
Nickel (Ni)	3.020±0.76	2.160±0.30	4.690±1.10
Manganese (Mn)	2.170±0.11	1.390±0.01	3.170±0.22
Arsenic (As)	0.066±0.00	0.074±0.01	1.130±0.02
Cadmium (Cd)	0.0011±0.00	0.0021±0.00	0.0067±0.00

Data represented as Mean±SD of triplicate measurements

Table 4: Spearman's correlation coefficient between metal concentrations in Agip, Iwofe and Mile III areas of Port Harcourt

Metals	Fe	Zn	Pb	Co	Cu	Cr	Ni	Mn	As	Cd
Fe	1									
Zn	0.312	1								
Pb	0.036	0.961	1							
Co	0.811	0.809	0.614	1						
Cu	0.598	0.948	0.822	0.954	1					
Cr	0.422	0.993**	0.921	0.873	0.979	1				
Ni	0.955	0.580	0.331	0.948	0.809	0.693	1			
Mn	0.982	0.486	0.224	0.907	0.739	0.586	0.994**	1		
As	0.799	0.821	0.630	1.000*	0.960	0.884	0.941	0.898	1	
Cd	0.689	0.903	0.749	0.983	0.993**	0.948	0.873	0.814	0.986	1

*Correlation is significant at 0.05 level (2 tailed and 1 tailed), **Correlation is significant at 0.01 level (1 tailed) generated during the slaughtering process. These secondary wastes included blood, fat, organic and inorganic content of the animal stomach and other chemicals that may be used during the process[22]. Heavy metals can also be generated from the dungs (faeces) and urine of the animals which are allowed freely on the nearby soil. Also the content of the dungs/urine may be directly related to the forage (food) from which the animals were fed.

Another source of heavy metals in the abattoir soil is the source of water from which the animals were washed and prepared for further processing. Naturally, the organic constituents that are generated in the abattoir are biodegradable and they undergo redox reactions through microbial and other chemical activities which heavy metals do not undergo. Heavy metals are persistent even for a long period of time with little or no change in concentration after introduction into any environment by man[23]. Plants, animals and humans are vulnerable to these heavy metals which possibly are transferred to the food chain, which when consumed result in bioaccumulation in important biochemical tissues/organs and therefore pose negative health implications such as diseases and death[1].

The very low concentration of the metals in the soils within the abattoir is an indication that anthropogenic sources may have contributed little or nothing to the concentration of these metals in the soil. The result of the heavy metals obtained may be an indication that the metals may have originated from the rock type or that the effect of erosion may have washed them away to the nearby streams, since all the abattoirs studied are situated close to streams. The concentrations of the heavy metals observed in this study were lower than those observed in other studies in dumpsites[24-27] but are higher than the concentration values observed in dumpsites in Yenagoa, Bayelsa state[28] and from abattoirs in Gboko, Benue state[1] and Abeokuta, Ogun state[29].

It has been observed[28-31] that certain metals (cadmium, arsenic, lead, etc. are always found in low concentration in the upper layer of the soil except when there is anthropogenic interference which is in agreement with the findings of this study.

The inter-relationship or association between the metals was analyzed by the Spearman's correlation coefficient model. The correlation relationship showed close association between Cr/Zn (0.993), Mn/Ni (0.994), As/Co (1.00) and Cd/Cu (0.993) which were significant.

These elemental pairs showed strong correlation significance. All metal pairs were positively correlated which is an indication that all the metals have common contamination source.

Pollution indices: The contamination factor and the pollution index of the metals from the various abattoirs are shown in Table 5. Applying the contamination factor as categorized[15], to interpret the data showed that the soil from the various abattoirs is not contaminated with Fe, Pb, Co, Cr, Mn and Cd in all the sample stations. However, soil from Mile III was found to be slightly contaminated with Zn and Ni. All the soils from the 3 stations were found to be contaminated with Cu. Mile III was slightly polluted with arsenic. When a comparative view of the three stations was taken to examine whether the soils were polluted by the heavy metals using the Pollution Index (PI) as categorized, it was observed that the soils are unpolluted by the metals.

The geo-accumulation index (Igeo) of the metals is shown in Table 6. The Igeo values calculated for the various metals were in the zero category indicating that the soils from the various abattoirs were uncontaminated[18]. This observation corroborates the findings of Osakwe[32] in a similar environment and activity in the Niger delta area, Nigeria.

Table 5: Contamination factor/pollution index for heavy metals in soils from the various abattoir

	Contamination factor		
Metals	Agip	Iwofe	Mile III
Iron (Fe)	0.00192	0.00156	0.00215
Zinc (Zn)	0.0583	0.0837	0.102
Lead (Pb)	0.0114	0.0227	0.0247
Cobalt (Co)	0.0012	0.00085	0.0185
Copper (Cu)	0.131	0.17	0.266
Chromium (Cr)	0.0094	0.019	0.0297
Nickel (Ni)	0.0863	0.0617	0.134
Manganese (Mn)	0.00255	0.0016	0.0037
Arsenic (As)	0.066	0.074	1.13
Cadmium (Cd)	0.00138	0.00263	0.00838
Pollution index	0.000	0.000	0.000

Table 6: Geo-accumulation index (Igeo) at different sampling station

	Contamination factor		
Metals	Agip	Iwofe	Mile III
Iron (Fe)	0.000310	0.000252	0.000346
Zinc (Zn)	0.0172	0.0247	0.0301
Lead (Pb)	0.00972	0.0194	0.0213
Cobalt (Co)	0.000253	0.000179	0.00391
Copper (Cu)	0.0210	0.0273	0.0427
Chromium (Cr)	0.00210	0.00424	0.00662
Nickel (Ni)	0.00891	0.00957	0.0138
Manganese (Mn)	0.000512	0.000328	0.000749
Arsenic (As)	0.00102	0.00114	0.0174
Cadmium (Cd)	0.000735	0.00141	0.00448

Table 7: Ecological risk factor of the various metals at the sample stations

		Contamination factor		
Metals	Tr	Agip	Iwofe	Mile III
Iron (Fe)	NA	NC	NC	NC
Zinc (Zn)	1	0.0583	0.0837	0.102
Lead (Pb)	5	0.057	0.1135	0.1235
Cobalt (Co)	5	0.12	0.085	1.85
Copper (Cu)	5	0.655	0.85	1.33
Chromium (Cr)	2	0.0188	0.038	0.0594
Nickel (Ni)	5	15.10	10.8	23.45
Manganese(Mn)	1	2.17	1.39	3.17
Arsenic (As)	10	0.66	0.743	11.30
Cadmium (Cd)	30	0.04	0.0789	0.2514

NA: Not available, NC: Not calculated

The potential ecological risk assessment of the heavy metals is shown in Table 7. The values calculated showed that the metals do not pose any ecological risk to the environment[19].

CONCLUSION

The quality of the top soil of any environment is very important to man. The results obtained for the heavy metals in the different abattoir indicated that the soil is uncontaminated by these metals. Index models applied to the result of the heavy metals revealed that the source of the metals in the soils from the abattoir were from anthropogenic sources. Also, the index models confirmed that the soils were unpolluted. However, the problem of pollution from these metals in these areas should be under routine check to avoid being polluted in the near future.

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